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EXPECTED PERFORMANCE GAIN OF A PROPOSED AN/SQS-26 DATA NORMALIZ--ETC(U)

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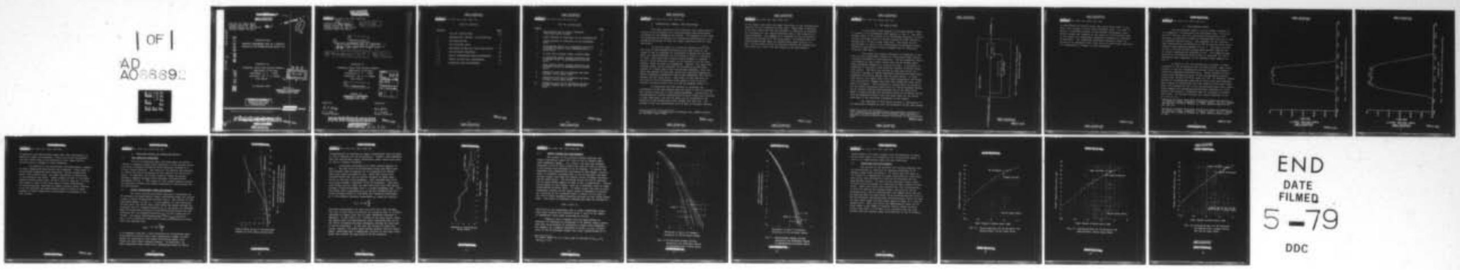

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Technical Note

EXPECTED PERFORMANCE GAIN OF A PROPOSED AN/SQS-26 DATA NORMALIZATION DEVICE (U)

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Submitted to

Commander, Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360
Attention: Mr. J. D. Hodges
Code PMS-87

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1. INTRODUCTION, SUMMARY, AND CONCLUSIONS

The work reported in this technical note gives partial results of an evaluation of a post-processing data-normalizing technique for the AN/SQS-26 CP channel. The purpose of the study of normalization techniques is to determine modifications to the AN/SQS-26 processors so that the output statistics will be time stationary.

It has been shown in a previous technical note[1] that the ratio of the standard deviation to the mean value at the output of the CP processor is essentially constant for an input which has fixed bandwidth but is varying in level as a function of time. This means that a device which produces a constant mean at the CP processor output, to be referred to as the mean-divider, might be used as a normalizer. However, for sonar echo ranging cycles, the CP processor is preceded by an AGC which results in a fixed input level and varying bandwidth, since the first few seconds of such echo cycles are typically composed of 100 Hz bandwidth reverberation which fades gradually into 130 Hz ambient and own ships noise. Thus there is time variation in the level of the CP processor output which is due to the CP channel correlator which acts as a 100 Hz bandpass filter.

An experiment has been devised to determine the performance of the mean-divider when the input to the CP processor has constant power but a time-varying bandwidth. Several sets of interference at various reverberation-to-noise levels were utilized in this experiment, and for any given set of interference the spectrum of the reverberation was constant for that set. The problem of how the mean-divider will be able to estimate the mean

[1] Investigations of Normalization Techniques (U), TRACOR Document No. 66-239-C, April 1966.

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of the output when there are rapid variations in the reverberation spectrum is not considered at this time. Under these conditions it has been shown that the mean-divider is effective in reducing the variations in the output statistics due to the variation in input bandwidth. For example if a threshold is set to produce a marking rate of one sec^{-1} for noise alone, the marking rate for this threshold when there is reverberation alone will be 3.5 sec^{-1} at the output of the CP processor whereas the marking rate would only be 1.5 sec^{-1} at the output of the mean-divider.

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2. THE MEAN-DIVIDER

A functional block diagram of the mean-divider (which is similar to a conventional AGC) appears in Fig. 1. The mean-divider input is the output of the CP channel processor (a 3-bit replica correlator with a ½ second clipped FM slide reference, followed by a 10 msec linear detector). The output of the mean-divider is equal to the instantaneous CP processor output divided by the processor output averaged over 20 resolution intervals (200 msec).

The output of a signal processor is normalized if the rate at which independent samples of noise-alone output exceed a display threshold is time-invariant. The un-normalized output investigated in this report occurs when the CP channel input noise bandwidth changes as a function of time. A variation in bandwidth is observed in the detection annulus of bottom bounce echo cycles. The first few seconds of such echo cycles are typically composed of 100 Hz bandwidth reverberation which fades gradually into 130 Hz ambient and own ships noise. In these echo cycles, the output noise level (and consequently the output noise statistics) changes with time even though the input noise power is constant. This variation in output level is caused by the CP channel correlator which acts as a 100 Hz bandpass filter. At one extreme (100 Hz reverberation) all of the input noise power is passed through the correlator while at the other extreme (130 Hz background noise), only the input power in the 100 Hz pass band of the correlator propagates to the output.

The remainder of this report contains a description of an experiment* designed to test the efficiency of the mean-divider

*This experiment was designed along the guidelines specified in USL Technical Memorandum No. 2131.1-1096-67, which outlines a program to evaluate various proposed techniques of data normalization.

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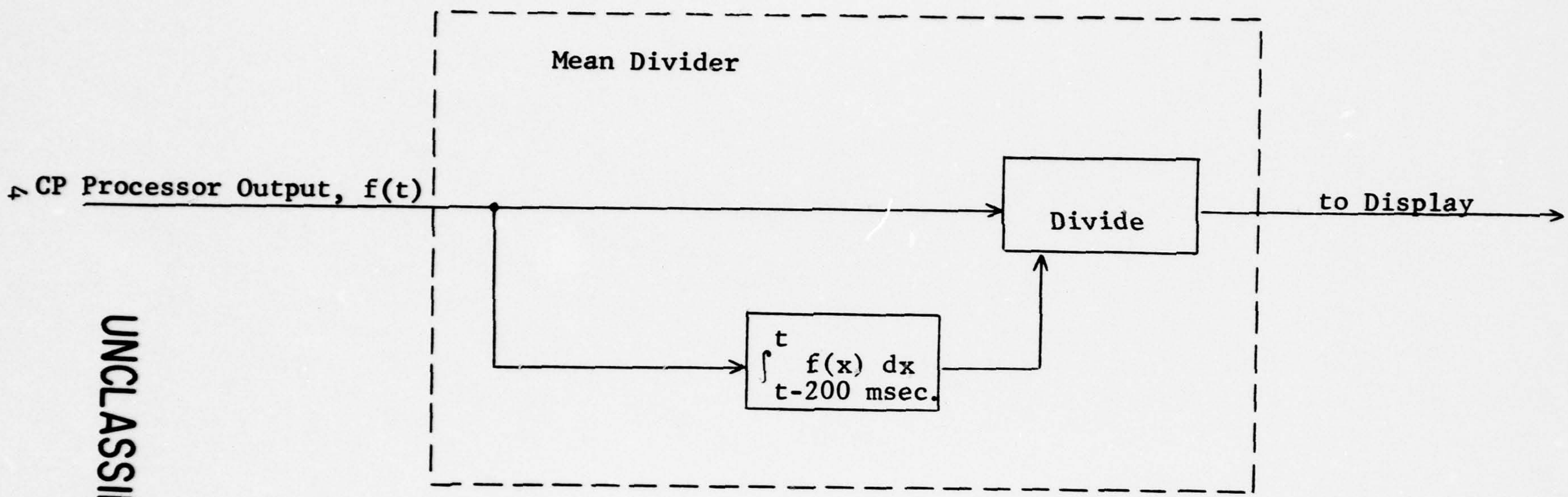

Fig. 1 - Mean-Divider for CP Signal Processor:
Functional Block Diagram

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in normalizing CP channel output when input noise power is constant, but changes in input noise bandwidth occur. In order to obtain a reasonable measure of mean-divider performance, mean-divider output was compared to the output of a CP processor and to the output of a postulated completely normalized or "optimum" CP Processor. The completely normalized processor output is assumed to be optimum in the sense that its noise-alone statistics are independent of changes in input bandwidth.

3. THE SIMULATED INPUT

The interference input to the CP channel consists of two components, reverberation and background noise. Previous results* indicate that the statistical distribution of CP processor reverberation cannot be distinguished from that of 100 Hz bandwidth Gaussian noise. The component of the simulated input representing reverberation is 100 Hz Gaussian noise whose computed power spectrum appears in Fig. 2. The power spectrum in Fig. 2 closely matches average power spectra computed for CP channel reverberation recorded at sea+. The computed power spectrum of the Gaussian noise chosen to represent the 130 Hz background noise component of the simulated input appears in Fig. 3.

In order to test the sensitivity to changes in input bandwidth of the CP processor and the mean-divider, input interference of various reverberation-to-noise ratios was prepared using the components described above. Twenty seconds of interference were generated at each of the reverberation-to-noise ratios from -20 dB to 20 dB in steps of 2 dB. In addition, twenty seconds of reverberation alone and of noise alone were prepared. Each example of interference was then scaled so that equal input power was obtained for all of the reverberation-plus-noise inputs. These examples of reverberation-plus-noise represent the interference that occurs at different times in a typical CP channel echo cycle. In the next section, the results obtained at the

*"Analysis of Signal Processing and Related Topics Pertaining to the AN/SQS-26 Sonar Equipment, A Summary Report, III (U)," TRACOR Document No. 65-336-C, October 11, 1965, Contract NObsr-93140, pp. 166-170.

+"Analysis of Signal Processing and Related Topics Pertaining to the AN/SQS-26 Sonar Equipment, A summary Report, II (U)," TRACOR Document No. 64-290-C, October 16, 1964, Contract NObsr-91223, p. 65.

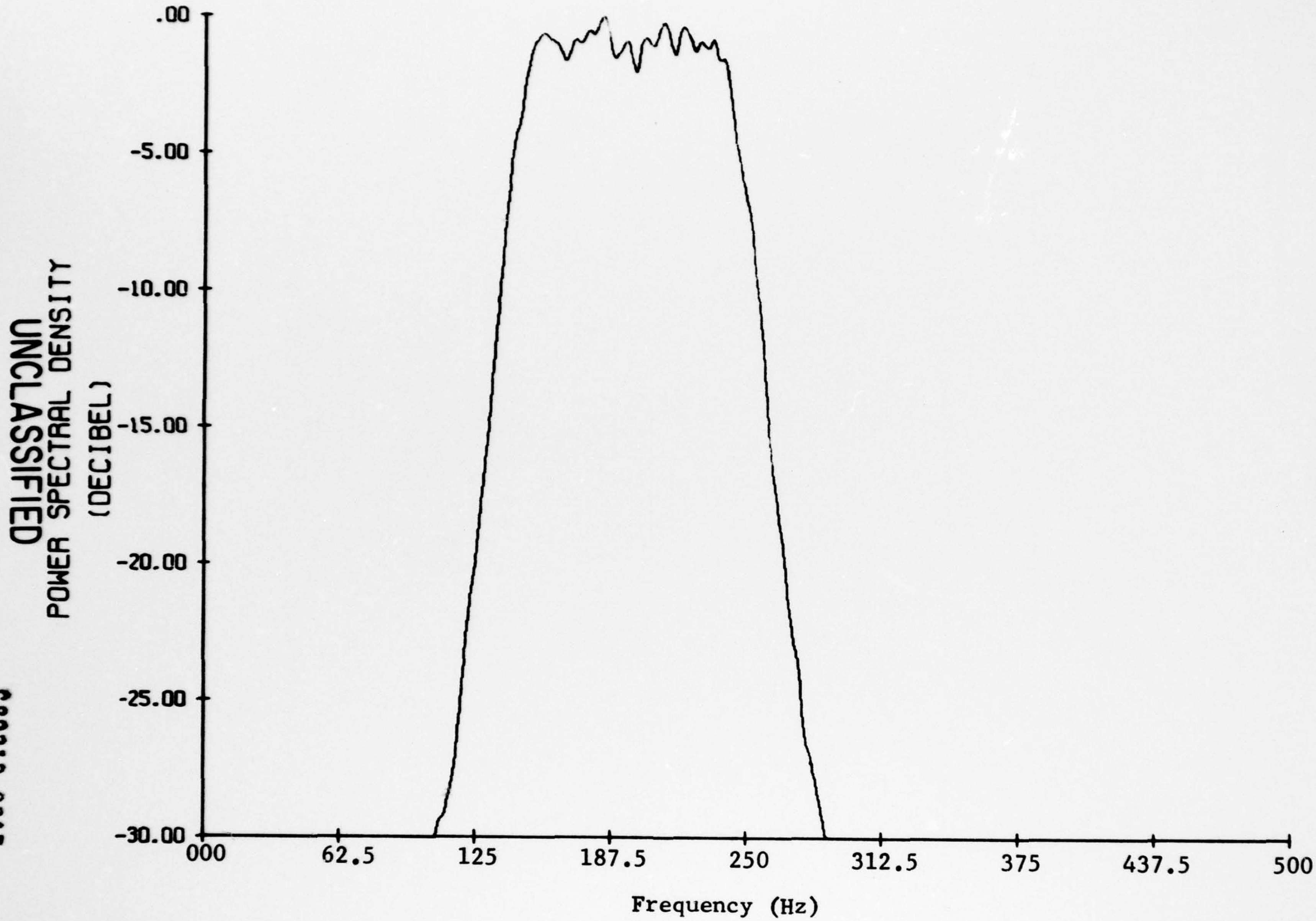

Fig. 2 - Power Spectrum of Simulated 100 Hz Reverberation

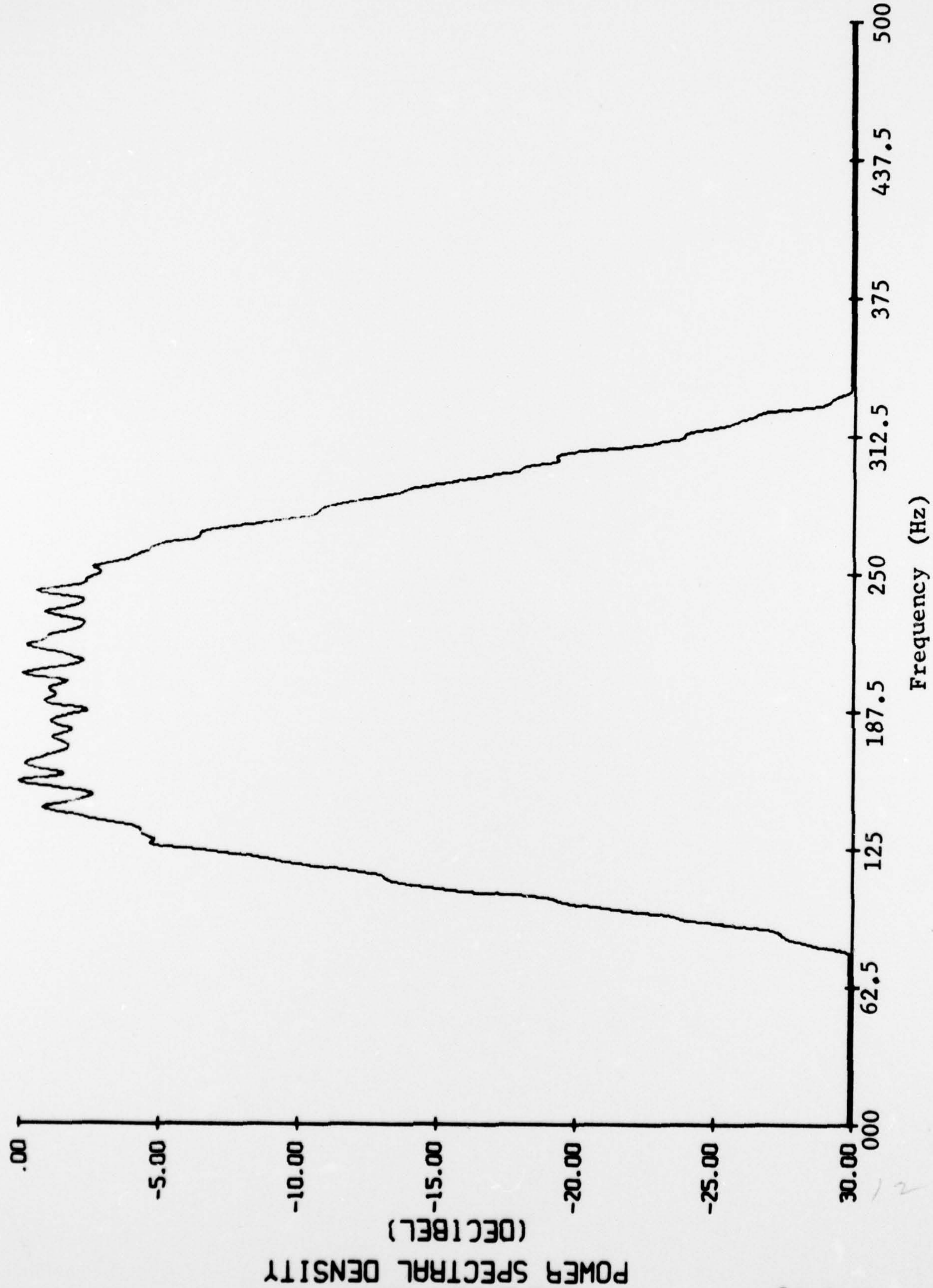

Fig. 3 - Power Spectrum of Simulated 130 Hz Background Noise

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CP processor and mean-divider output when this interference is applied at input are presented. Since all of the interference has equal input power, any variations in the output will be caused solely by changes in input bandwidth.

In addition to the interference described above, examples of input signal-plus-interference were prepared. Three types of interference background were considered, 100 Hz reverberation alone, 130 Hz noise alone, and input consisting of equal parts of reverberation and noise. Twenty signals at each of the input signal-to-noise ratios from -15 dB to 0 dB in steps of 3 dB were then added to each of the three types of input interference. The processing gain (increase in signal-to-noise ratio) obtained at the CP processor and mean-divider output of each of these examples of input signal-plus-interference is presented in the next section.

4. PROCESSING METHOD AND SIMULATION RESULTS

4.1 THE SIMULATED PROCESSORS

All of the simulated input described above was passed through a computer program which simulates a 3-bit replica correlator with a clipped ½ second FM slide reference followed by a 10 msec linear detector. The output of the detector was analyzed to obtain the results presented in this section for the CP processor. In addition, the 10 msec detector output was passed through a computer program which simulates the mean-divider diagrammed in Fig. 1. The output of this second computer program was analyzed to obtain the results presented in this section for the mean-divider.

4.2 OUTPUT INTERFERENCE POWER MEASUREMENTS

The first analysis performed consisted of measuring the CP processor and mean-divider output interference power for various values of input reverberation-to-noise ratio. The results of this experiment appear in Fig. 4. A curve appears for each processor. In each case, the 130 Hz input noise alone was passed through the processor and the standard deviation σ_N of the output was obtained. Each 20 second input section of reverberation-plus-noise was then processed and the standard deviation σ_{R+N} of this output was obtained. The output interference power level P_{R+N} plotted in Fig. 4 for a particular value R+N of input reverberation-to-noise ratio was obtained from

$$P_{R+N} = 10 \log \frac{\sigma^2_{R+N}}{\sigma^2_N} .$$

It is apparent from Fig. 4 that variations in CP processor input reverberation-to-noise ratio (and consequently changes in bandwidth) are reflected in the output interference power, even though the input power remains constant. In particular, as input bandwidth varies from 130 Hz (background noise) to 100 Hz

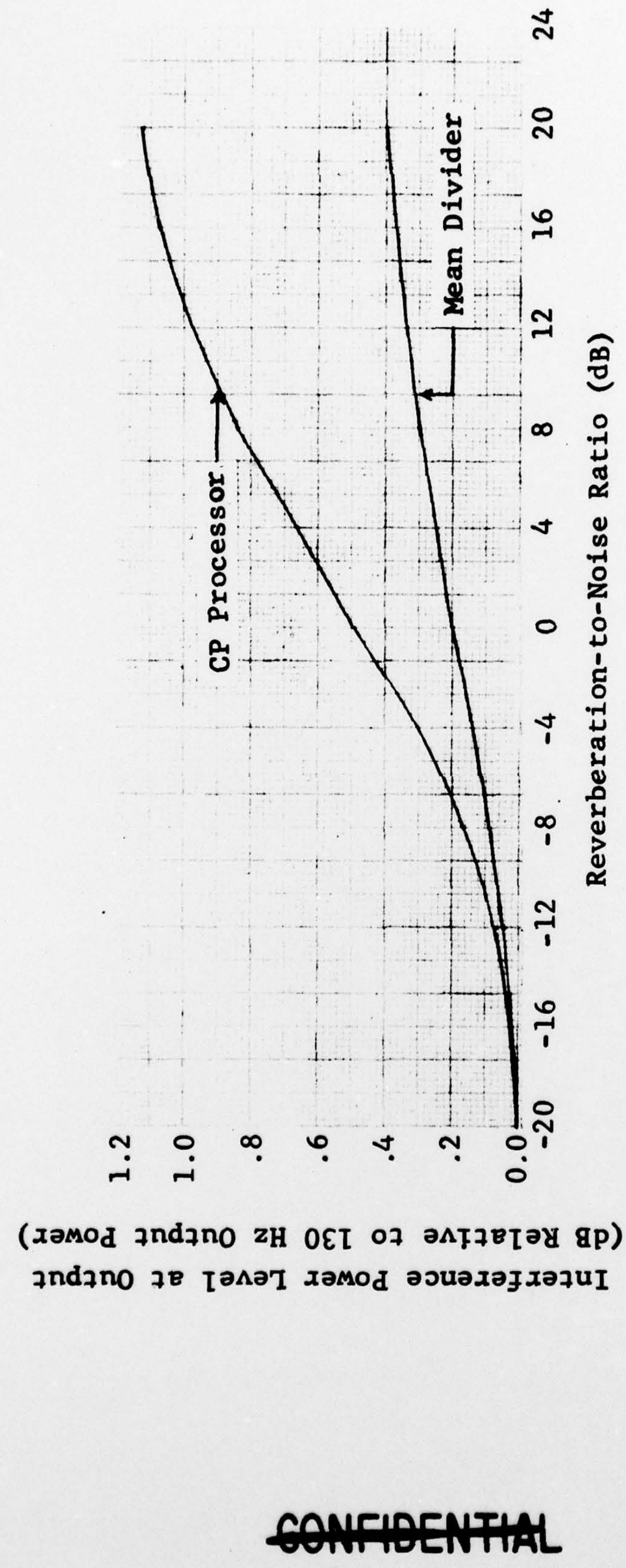

Fig. 4 - Interference Power at CP Processor Output for Different Values of Input Reverberation-to-Noise Ratio

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(reverberation) an increase in output interference level of about 1.1 dB is observed for the CP processor. Figure 4 also indicates that the mean-divider output interference power varies only about 0.4 dB in a similar situation.

A practical verification of these results appears in Fig. 5. The two curves of CP processor output and input power were obtained from an analysis of 16 consecutive CP channel input echo cycles recorded at sea. These echo cycles were recorded before AGC, and an overall decrease in input power occurs as the echo cycles progress. Each recorded echo cycle was passed through a simulated 12-bit CP processor. This processor output and the input for each echo cycle were then passed through a detector-averager with a 1 second averaging time. Relative power level measurements P_R in dB were obtained from the 1 second averaged output by referring each intensity measurement p_i to the minimum intensity measurement p_m using the relation

$$P_R = 10 \log \frac{p_i^2}{p_m^2} .$$

The power measurements for each echo cycle were then averaged over the 16 echo cycles to produce the curves in Fig. 5, in which variation in output level due to input bandwidth variation is apparent. In the first 6 or 7 seconds of the echo cycles, input and output power are approximately equal indicating that all of the 100 Hz reverberation power propagates through the pass band of the CP correlator. In the last few seconds of these echo cycles, however, the input power becomes greater than the output power, indicating that a significant fraction of the input noise power lies outside the pass band of the CP processor.

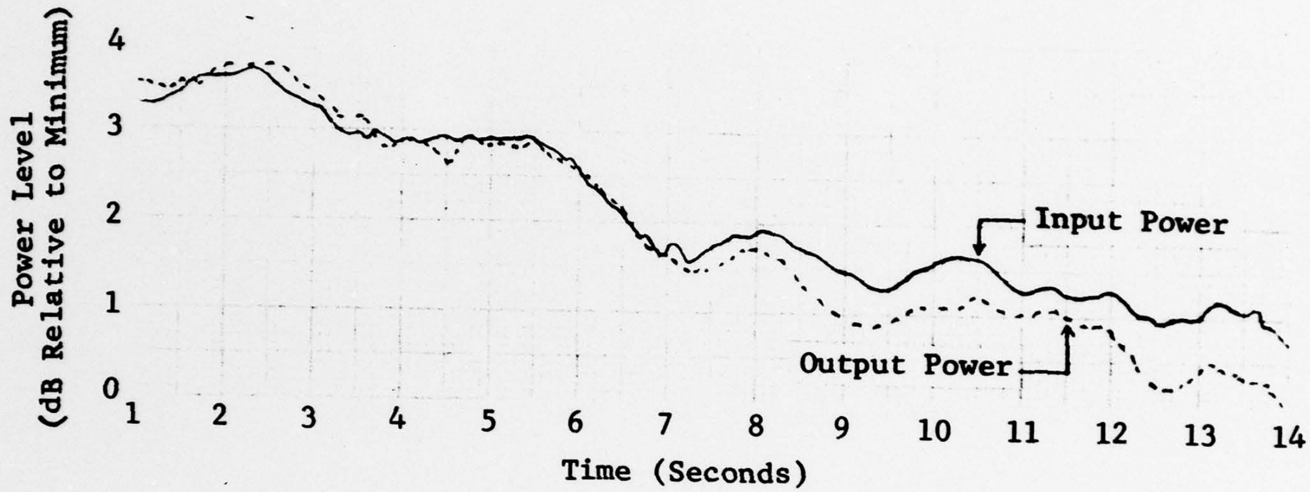

Fig. 5 - 16 Echo Cycle Average Input & Output Power

4.3 OUTPUT CLUTTER RATE MEASUREMENTS

The results of the previous section indicate that output interference power will vary as the CP channel input noise bandwidth changes. As a result, the mean and standard deviation of the CP noise output will vary and tend to produce a non-uniform noise marking of the CP display. To measure the departure from normalization introduced in this manner, calculations of threshold crossing rates at the CP processor and mean-divider outputs were made for various values of input reverberation-to-noise ratio. The resulting curves for the CP processor and the mean-divider appear in Figs. 6 and 7 respectively. Several curves appear in each figure, each for a different value of input reverberation-to-noise ratio. In these curves, the rate at which independent samples of the output exceed a threshold is plotted as a function of the threshold value T, where T is in units of the 130 Hz output standard deviation relative to the 130 Hz output mean. The values of threshold crossing rate R(T) are defined by

$$R(T) = P(T) \cdot N ,$$

where P(T) is the probability that a single independent output local peak* exceeds the threshold value T, and N is the number of independent local peaks occurring per second.

Figures 6 and 7 indicate that the mean-divider is effective in reducing the variations in CP channel output clutter rate that occur because of variations in input noise bandwidth. For example, if a display threshold of value 2 is set, clutter rates at the CP processor output vary from 7 marks/second to 11

*An output sample X_i is a local peak if and only if $X_{i-1} < X_i$ and $X_{i+1} < X_i$.

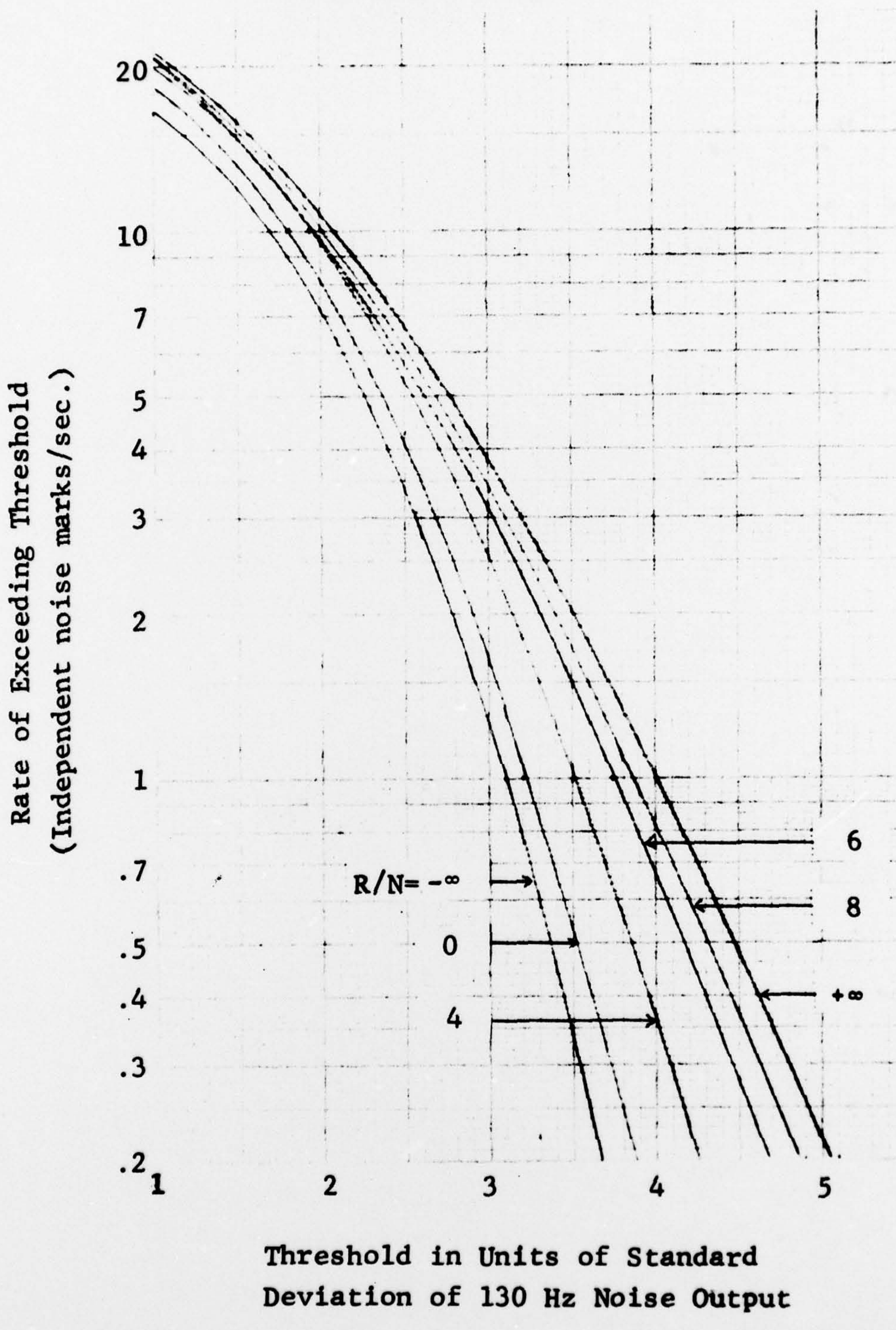

Fig. 6 - CP Processor Output Clutter Statistics for Different Values of Reverberation-to-Noise Ratio

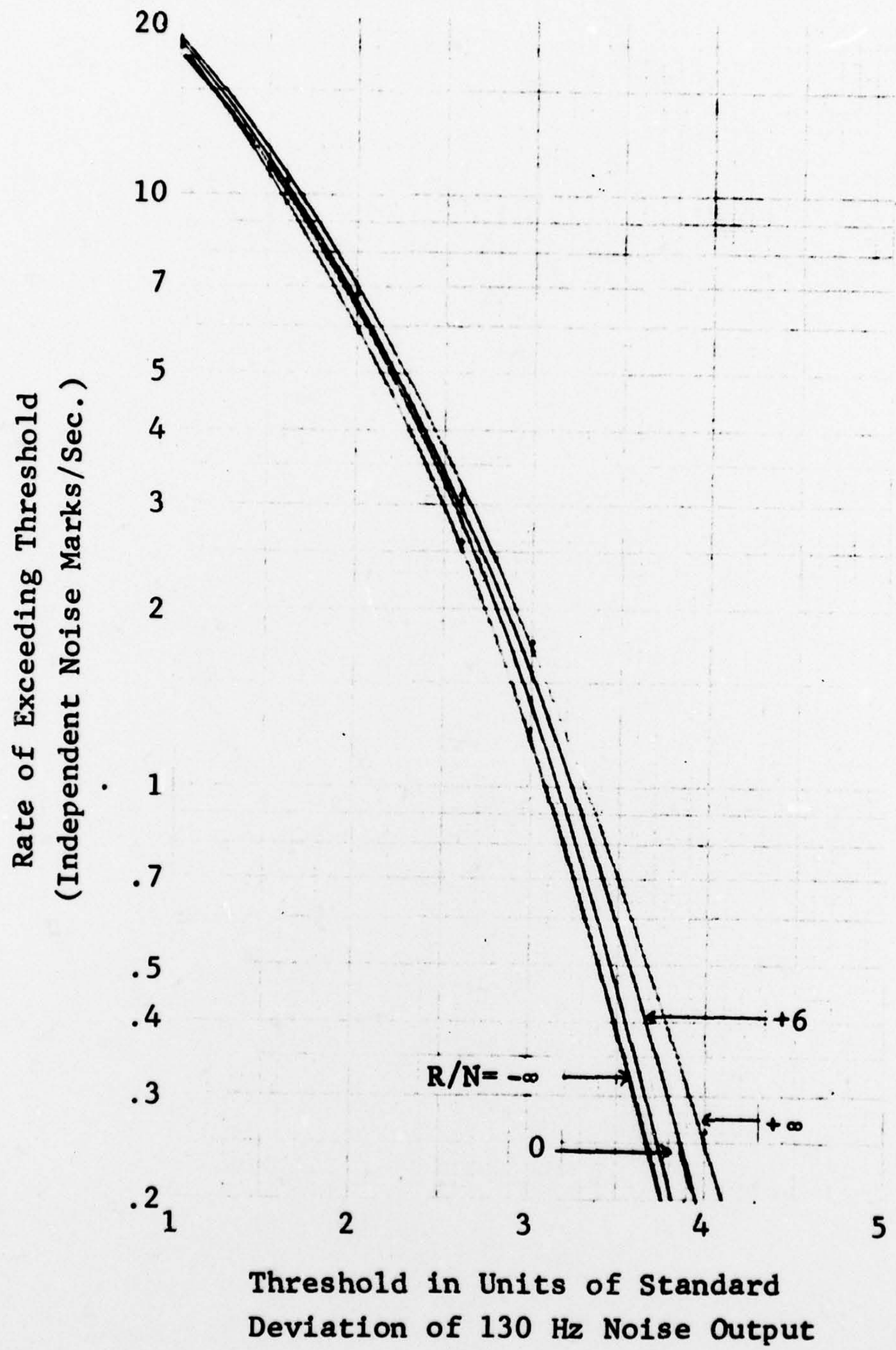

Fig. 7 - Mean-Divider Output Clutter Statistics for Different Values of Reverberation-to-Noise Ratio

marks/second as the input changes from reverberation to noise. On the other hand, the variation at the mean-divider output is from 6 to 7 marks/second under the same conditions.

4.4 PROCESSING GAIN MEASUREMENTS

The results in the previous two sections indicate that the mean-divider is effective in reducing variations in CP channel output noise statistics. To insure that this gain is not offset by a degradation in signal detectability, processing gain curves were obtained for both the CP processor and the mean-divider output. In these curves processor output signal-to-noise ratio is plotted as a function of input signal-to-noise ratio. Three such curves were obtained for the two processors, a curve for each of the assumed inputs consisting of 130 Hz Gaussian noise, 100 Hz reverberation, and summed 100 Hz and 130 Hz Gaussian noise of equal power (0 dB reverberation-plus-noise). The CP processor and mean-divider processing gain curves for each of these three types of noise input appear in Figs. 8, 9, and 10 respectively. Since the curves are approximately equal in all three cases in the range of interest (output signal-to-noise ratios from about 4 to 14 dB), it is concluded that the mean-divider does not degrade signal detectability on the CP channel.

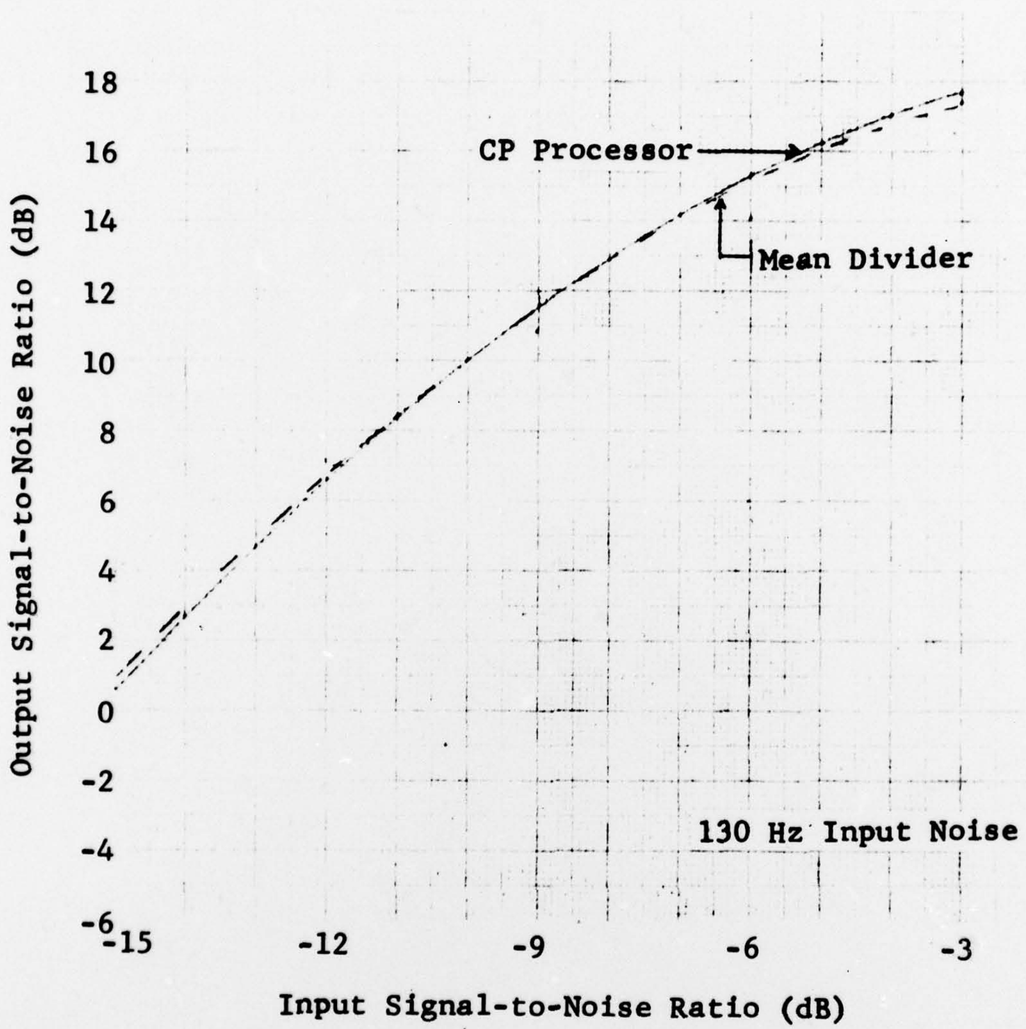

Fig. 8 - Processing Gain for CP Processor and Mean-Divider, 130 Hz Input Noise

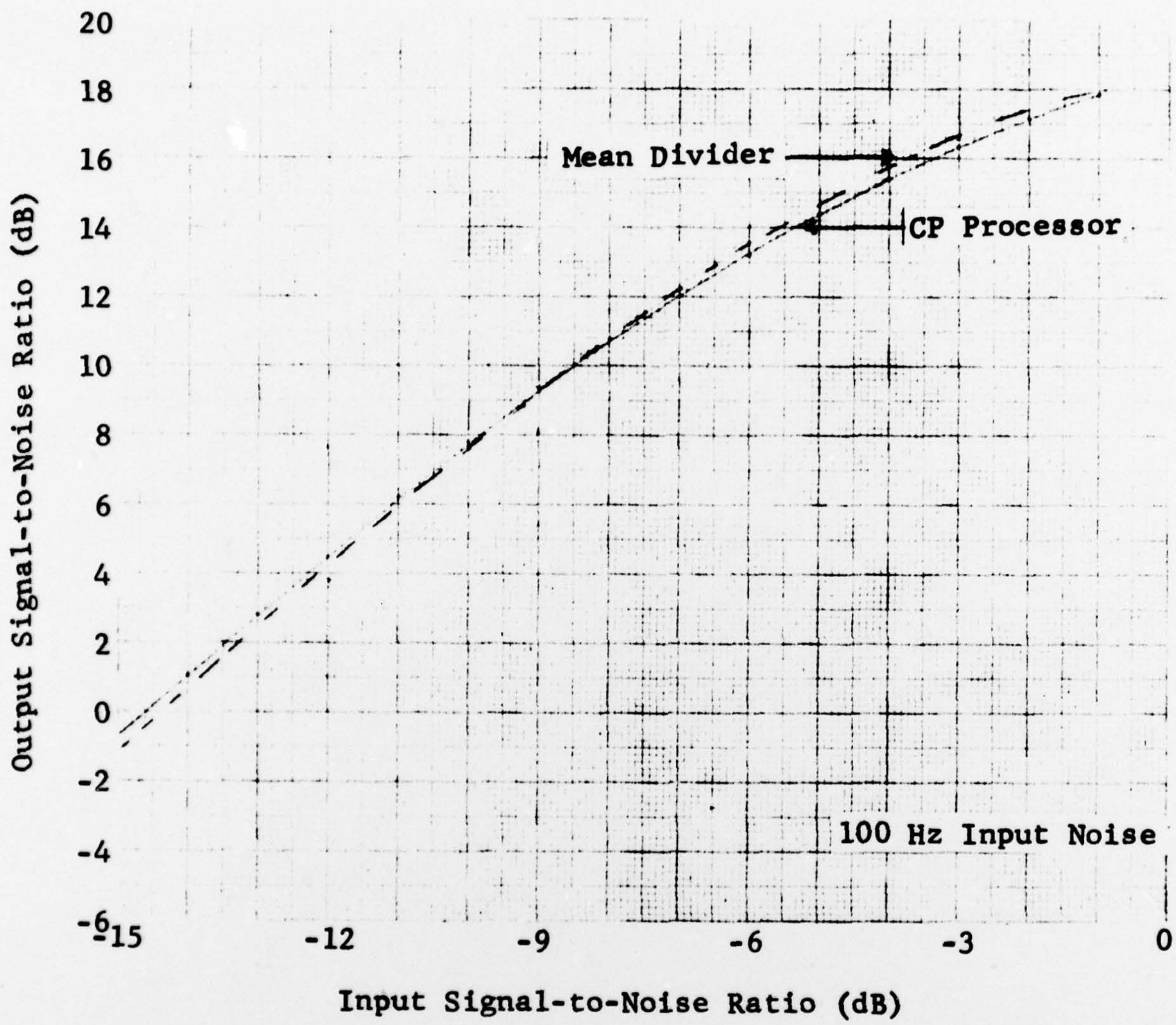

Fig. 9 - Processing Gain for CP Processor and Mean-Divider, 100 Hz Input Noise

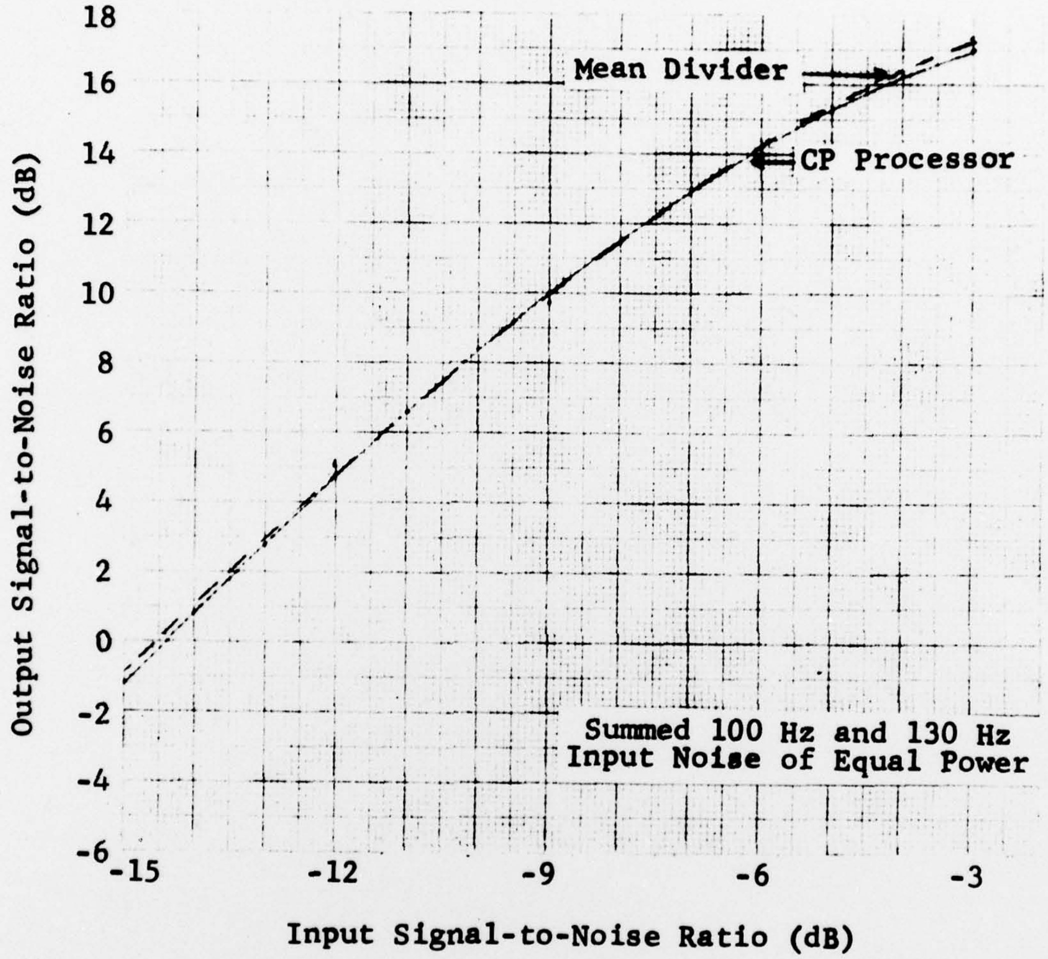

Fig. 10 - Processing Gain for CP Processor and Mean-Divider, Summed 100 Hz and 130 Hz Input Noise